SelPiBioLife for black pine stands

A silvicultural strategy for artificial pine stands established for different purposes

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LIFE13 BIO/IT/000282
Prodotto realizzato con il contributo dello strumento finanziario LIFE dell'UE

SelpiBioLife is a project finalized at demonstrating the positive effects of a specific silvicultural treatment (selective thinning) on black pine forests. Selective thinning improves growth rates and stand stability and enhances the biodiversity of soil components (flora, fungi, bacteria, mesofauna, nematods and microarthropods). The present paper illustrates the first results of two different thinning approaches (traditional and selective) in two artificial black pine forests characterized by different site and stand features and different forest management strategies.

Forest policy in the Apennines over the 20th century was aimed at the reforestation of mountainous areas depleted by the intensive use of natural resources. Main purpose of reforestation was the protection of mountain slopes by a new-established vegetation cover. Black pine was widely used across Italy because of its characteristics of pioneer species suitable to reforest mountainous degraded areas.

According to the second National Forest Inventory (2005), black pine (*Pinus nigra* J.F. *Arnold* sp.) stands in Northern and Central Apennines cover an area of 8,750 ha. At present, 5% of these stands are at the stem exclusion stage, 54% young high forest and 42 adult high forest. These stands are among the most simplified forest systems in Italy, mostly occurring in pure, even-aged stands.

A wide discussion on the role of black pine forests and their evolution has arisen in the last years. From one side, the pioneer role of these stands has been recognized. From another side, the massive use of black pine has been criticized for its impact on biodiversity at the various scales. Following this 'wave', an "anti-pine fervor" as defined by Bernetti (2000), has taken place and concretized in policies and practices finalized at favoring the "renaturalization" of black pine stands, since its early developmental stages. In a few cases, forest laws have pursued this trend. The case of Tuscany, where a rotation period of only 40 years is applied (Cantiani 2012), is emblematic. Despite these forests are similar from the viewpoint of forest structure, specific forest strategies can be adopted at the local level as a function of the main functions of the stand, both in the public and in the private ownership.

This paper summarizes the main goals and preliminary results of the SelPiBioLife Project, which demonstrates the applicability of a silvicultural strategy in two black pine forests, characterized by a different history, environmental and socio-economic features, main functions and final destinations.

The project

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SelpiBioLife project "Innovative silvicultural treatments to enhance soil biodiversity in artificial black pine stands" (LIFE13 BIO/IT/000282) has the main goal to demonstrate that a sustainable silviculture in pine stands with easy and replicable interventions is possible. Trials are based on silvicultural treatments optimizing both productive and protective functions, and the level of biodiversity of the various soil components (flora, fungi, bacteria, mesofauna, nematods and microarthropods).

As a consequence, it is also easier to develop long-term management strategies in a vigorous and resilient stand, where a suitable silviculture is being implemented.

The experimental protocol of SelPiBioLife is based on the comparison of two silvicultural treatments: (i) the traditional thinning (moderate thinning from below) and (ii) the selective thinning. Both dendro-structural parameters of the stands and the level of biodiversity of soil components were measured before and after treatment. The study areas are located in Tuscany, in the area of Pratomagno (Arezzo) and of the Amiata (Siena). More information are available on the website *www.selpibio.eu*.

Wood assortments	Lenght (m)	Diameter (over bark)	Allocation	Price(*) (sale at the timber yard)
roundwood	> 4 m	> 30 cm at top	pallet or sawlog	3,00 €/q
shorts (stangame)	> 4 m	< 30 cm at base (until 10-12 cm at top)	pallet	2,50 €/q
poles	5-5,40 m	18 cm < diametro al calcio < 30 cm	naturalistic engineering	4,00 €/q
wood residues	All wood out of previous assortments		wood chips	1,60 €/q

(*)*Current average prices at public auctions of Mountain Communities in Casentino.*

Table 1 - Sizes and allocation of wood assortments achievable from Tuscany black pine stands drawn from a local assortment Table (Rinaldini 2016).

Management of pine stands. History and future strategies

Pine stands of Pratomagno

The "Pratomagno" forest district is located in the north-west of the Arezzo province, Tuscany region (43_390 N 11_390 E). The Pratomagno forest area covers 2,820 ha and black pine stands count about 17% of the area. The pine cover is the outcome of a reforestation programme, started in 1954 and ended in the late 1980's.

The main aim was the reafforestation of degraded areas and the protection of soil from the excessive erosion.

Among the many black pine subspecies, the main used in the early years of reforestation in Italy was the laricio pine (*Pinus nigra* ssp. laricio). However, Austrian pine (*Pinus nigra* ssp. nigra) was commonly used, even if preferred in low fertility areas (especially pasture ridges).

Since 1980, three management plans have been implemented in the Pratomagno district, the last one will be effective until 2021. Concerning Austrian pine, the management strategies have changed in the course of the years; the first two plans were mainly focused on silvicultural guidelines such as (cleaning in thickets and thinning in the pole stage). The last plan gives first indications for the overall forest management of the pine stands: the forest strategy is oriented to facilitate the transition towards a stratified mixed forest through targeted interventions (tree-oriented silvicultural method). (D.R.E.Am 2007).

Pine stands of Amiata

The history of reforestation in Amiata is closely linked to the decline of mining activity in the area. One of the most important reasons that determined the reafforestation activities was to find out a solution to the unemployment due to the mining sector crisis, with "socially useful activities" (Gatteschi and Fedeli 1994). There were up to 600 men at work on the reafforestation and the hydraulic arrangements of the slopes.

Since the beginning of the 1950s to mid-'90s the areas surrounding the Monte Amiata were reforested with about 3,700 ha of conifers. Prior to the Second World War (especially between 1922 to 1933) around 1.000 ha had been reforested mainly with black pine and silver fir. To this purpose, funding was provided by public sources or the mining companies. Actually, the activity depended on the flow of ad hoc public funds.

The project area, namely "Madonna della Querce" in the 1960s becomes property of the Agency for State-owned forests. The ownership was subsequently transferred to the Tuscany Region and further expanded to the current area of 2,177 ha.

In the Amiata forest planning activity started in the '80s and until the last forest plan, the customary treatment of black pine stands included cleaning in early developmental stages, thinning from below in more mature stages, a rotation of about 70 years with clear-cutting and postponed artificial regeneration with native species preferably when the pine forest had played its restoration role (Pavari 1961).

Management guidelines of the last forest plan indicate to favour natural regeneration of autoctonous species, with silvicultural interventions characterized by short rotation period (shelterwood system).

Silvicultural treatment of SelPiBioLife

SelPiBioLife Project aims to show the effects of the selective thinning on black pine forests. The characteristics of the intervention are detailed in a technical handbook realized during the development of the Project (*https://goo.gl/3Y90TN*).

Main features of the selective thinning are:

- the selection of 100 trees per hectare based on the quality of phenotype, i.e. its mechan-

		Thinning from below		Selective thinning	
		m³	€	m³	€
Combination 1	Roundwood	3,1	84	24,7	667
	Shorts	131,3	2.954	223,5	5.029
	Wood Residues	9,3	134	30,0	432
	Total	**143,7**	**3.172**	**278,2**	**6.128**
Combination 2	Poles	94,5	3.402	181,6	6.538
	Roundwood	3,1	84	24,7	667
	Wood Residues	46,1	664	71,9	1.035
	Total	**143,7**	**4.150**	**278,2**	**8.240**

Table 2 - Amiata study area: comparison of volume and prices related to the wood assortments (fresh wood density = 0,90 g/cm³ Giordano 1981).

		Thinning from below		Selective thinning	
		m³	€	m³	€
Combination 1	Roundwood	20,6	556	85,2	2.300
	Shorts	151,5	3.409	194,0	4.365
	Wood Residues	16,8	242	35,0	504
	Total	**188,9**	**4.207**	**314,2**	**7.169**
Combination 2	Poles	121,3	4.367	162,1	.5836
	Roundwood	20,6	556	85,2	2.300
	Wood Residues	47	677	66,9	963
	Total	**188,9**	**5.600**	**314,2**	**9.099**

Table 3 - Pratomagno study area: comparison of volume and prices related to the wood assortments (fresh wood density = 0,90 g/cm³ Giordano 1981).

ical stability and vigour (candidate trees);
- making candidate trees free from their direct competitors, i.e. all the surrounding trees limiting the full crown growth of the candidate tree.

The average number of candidate trees should be around 100 trees per hectare. The density of 100 trees per hectare (10 meters the average distance between trees) comes from the analysis of crown development patterns of black pine in the absence of lateral competition (Bernetti *et al*. 1969, Cantiani and Piovosi 2009) and by experimental data measured at this purpose. The aim of thinning is to leave free space available to the crowns of candidate trees. A new thinning should be made at the time the crowns of candidate trees will get in touch and overlap the ones of competitor trees.

Elements of strength of the method proposed are as follows:
- it is a thinning system of simple enforcement, easily reproducible and rather flexible;
- it stimulates the short-term increase mechanical stability at the stand level;
- it ensures a higher yield both in terms of timber amount harvested, and as quality of the assortments. In addition, the micro gaps created, i.e. the spaces opened at the canopy level, originate microclimate variability at the ground level with benefits for biodiversity.

Comparison between thinning from below and selective thinning

Wood production function

Table 1 shows the main features and destinations of wood assortments harvested ned from black pine stands in Tuscany. Data are drawn from a local assortment Table (Rinaldini 2016)

Noteworthy among the black pine assortments is the pilework because it gets the highest price. It is used in naturalistic engineering as supporting framework for reinforcements, or embedded into marshy soils as foundations to walls. All what is pilework may be used as short, but not vice versa. Processing residuals may be used for packing.

The local assortment Table allows the evaluation of two possible combinations of wood assortments:

1. roundwood - shorts - wood residues
2. poles - roundwood - wood residues

Table 2 and 3 show the two possible combinations of wood assortments for the Amiata and Pratomagno study areas. Prices and volumes of wood assortments are shown both for the selective and traditional thinning for each combination.

Protective function

Thinnings gives rise to effects on stand stability in the medium-long run. Thinning produces a higher growth of trees due to the reduction of stand density and, consequently, it lets the mechanical stability at stand level to increase (smaller H/D ratio, higher crown ground coverage, higher crown symmetry).

Selective thinning - stimulating the growth of candidate trees i.e. the most vigorous trees - is very suitable for improving the dominant layer stability.

In the two study areas, the Hegyi competition index (Box 1) was also calculated, referred to the candidate trees selected with the selective thinning criterion. After the selective thinning, the Hegyi competition index decreases of 35% in Amiata and of 30% in Pratomagno, due to the lower competition level acting. When considering the trees hypothetically candidates following the traditional thinning intervention, the reduction is of 32% (Amiata) and 27% (Pratomagno), respectively.

Biodiversity

BOX - HEGYI COMPETITION INDEX

$$\sum_{i=1}^{n} \frac{DBHj}{DBHi * dist}$$

where
DBHi= diameter at breast height (cm) of competitor tree;
DBHj= diameter at breast height (cm) of reference tree;
dist= horizontal distance between trees i and j (m)

Within the selective thinning case, other - sporadic species - may be selected as candidate trees. A good practice implementation foresees the choice as candidates of those trees answering for a good reaction to the treatment and for the ability to disseminate in the phase of natural regeneration.

Selective thinning, changing both the horizontal and vertical layering, originates the stand structure variation. This change will affect microclimate at the soil level in terms of incoming light and water, increasing the environmental diversity and thus the biotic diversity (shrub and herbaceous flora, mycological component, meso-and micro-fauna, bacteria in the

	Thinning from below			Selective thinning		
	Before	After	Variation	Before	After	Variation
Amiata	15,9%	21,75%	5,8%	8,5%	36,9%	28,4%
Pratomagno	13,8%	34,4%	20,6%	12,4%	40,7%	28,3%

Table 4 - Mean values of photosynthetically active radiation (PAR) in the two study areas before and after thinning practices.

soil) (Chapter 4 - Manuale SelPiBio 2016).

The canopy cover reduction due to selective thinning determines the increase of photosynthetically active radiation (PAR). Table 4 highlights that in the Amiata study area, following the selective thinning, PAR increases of 28.4%, while after the customary thinning the increase is of 5.8%, only.

Similarly, in the Pratomagno study area, PAR increases of 28.3% after the selective thinning and of 20.6% following the traditional practice. As for crown cover, 13% was removed with customary thinning and 20% with selective thinning.

Selective thinning contributes to increase the patches of light randomly on the ground. The sequence covered-uncovered determines the increase in the diversity of undergrowth flora and mycological flora, making possible shade-tolerant and light-demanding species to coexist (Cantiani *et al*. 2015).

Conclusions

Black pine plantations well reflect both the ecological and socio-economic characters of the areas where they are located. The evolution of the Apennine artificial stands depends on the local forest policies and on the resulting forest management choices. These choices set up the rotation time and the criteria of succession and regeneration of tree species. The alternative choices range from clear cut and short rotation periods with tree species substitution to natural regeneration criteria based on group selection cutting, shelterwood, strip cutting. Even natural ageing of standing crop is a choice, based on the natural regeneration in the openings created following the fall of the previous cycle trees.

We can say that the appropriate management of black pine plantations during the juvenile phase, i.e. with thinnings implementation, seems to be crucial for the increase of ecological, economical and protective values of these artificial stands.

Thinnings on such low productive high forests as black pine plantations are, as a rule, a cost for the manager. This is why interventions should be as effective as possible for the improvement of all the forest functions, minimizing in this way the cost/benefit ratio.

Selective thinning proposed by the SelPiBioLife Project is consistent with this strategy.

The key points of the treatment are as follows: (i) the incisive treatment to produce an effective growth increment and improvement of the candidate trees shaping (productive and protective function as well); (ii) the implementation of an optimal microclimatic environment for increasing both flora and fauna biodiversity.

We believe that the easy enforceable and reproducible rules for selective thinning will support the action of forest technicians.

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Abstract: *In Italy, the diffusion of black pine plantations is mainly linked to the pre-existing local orographic and social conditions. The main goal of the SelPiBioLife project (LIFE13 BIO/IT/000282) is to demonstrate the positive outcomes of the selective thinning scheme under the economic and ecological point of view, in comparison to the more classical approach of thinning from below. With this treatment, the attention is focused just on 100 candidate trees per hectare which must grow free from competition of surrounding trees. Two study areas were selected and submitted to thinning trials in 2015 with this thinning system, in the Monte Amiata and in the Pratomagno districts. Each of them shows a similar ecological profile but different history and future perspectives. The SelPiBio approach demonstrated the chance to improve the ecological system. An enhanced amount of solar radiation at the soil was detected, localized all around the candidate trees, it improving the spatial variability across the pinewood plantation. In addition, a higher quality and amount of timber was harvested according to this thinning scheme, both in terms of total volume and timber.*

Keywords: *Silviculture, selective thinning, Pinus nigra, SelPiBio LIFE, biodiversity*

Acknowledgments

This study has been carried out and funded by the SelPiBio LIFE project (Innovative silvicultural treatments to enhance soil biodiversity in artificial black pine stands, LIFE13 BIO/IT/000282) for demonstration of innovative silvicultural treatments in artificial black pine stands. We would like to thank all the partners and other people who collaborated to collect data and information for the implementation of this research.